TOPIC REPORT: SAVINGS OPPORTUNITIES

Connecticut C&I Lighting Saturation and Remaining Potential Study

Report Prepared for the Connecticut Energy Efficiency Board

Report No.: C2014-A
Date: June 30, 2022
Prepared By: Geoffrey Cooper and Sue Haselhorst, DNV

1 ABSTRACT

As part of the Connecticut C2014 Commercial and Industrial (C&I) Lighting Saturation and Remaining Potential Study, DNV investigated savings opportunities around three key lighting-related themes: TLED to LED luminaire conversions, adding enhanced lighting controls capabilities to existing LEDs, and commissioning. The results of these investigations are based on interviews with five lighting experts and additional data from research conducted in Connecticut and similar jurisdictions.

In general, there is no perfect solution for replacing the declining C&I lighting program savings. As the natural adoption of LED technology continues to increase, there are a few strategic areas that program administrators should consider. At this point in the market transformation, program administrators should continue to shift the focus from the traditional TLED market towards the more advanced LED luminaires with lighting controls. It is very challenging to add advanced control capabilities after installation, so it's essential to encourage the adoption and accurate commissioning of advanced technologies. The following summarizes the key market insights around the three topics:

TLED to LED Luminaire Conversions

Market Insight 1: The natural adoption of standard TLEDs has reached or is close to the peak of the market, and the price of TLEDs has decreased from historical rates to a point where there is now minimal opportunity for programs to generate significant savings moving forward. However, there may still be pockets of customer segments where TLED incentives can transform the market and deliver benefits, like in EJCs. Programs incentives for controllable technologies, like networked TLEDs or LED luminaires with advanced or networked controls, are still needed to push customers towards controllable technologies to mitigate the impacts of stranded savings

Market Insight 2: Since many customers are satisfied with the performance of the TLEDs and there is some uncertainty around what types of situations or conditions where it would be cost-effective to replace TLEDs with LED luminaires, the opportunity for a targeted TLED replacement program is likely minimal. However, there may be some situations where replacing a TLED with LLLCs or luminaires with NLC may but cost-effective, but more work is needed to understand the benefit-cost ratio and customer willingness-to-pay for these types of projects.

Adding Controls to Existing LED Systems

Market Insight 3: it's challenging, although not impossible, to add controls after LEDs are already installed. For older TLED systems, this is especially challenging. For newer LED luminaires installed without controls, it may be easier to install controls after a project is completed, especially given the technology improvements and new DLC standards for luminaires. Given these challenges, it's important to incentivize controls capabilities as part of the initial install/project.

Commissioning Advanced Controls

Market Insight 4: Savings from lighting controls systems are dependent on the installation and appropriate commissioning, which is dependent both on the space type and usage patterns. Pre-commissioned fixtures will have some savings, but don't necessarily maximize the savings opportunity. Continued contractor training is an important tool for ensuring that these fixtures are commissioned accurately. Tracking the specific controls capabilities of installed fixtures, and to what extent they are being deployed correctly, can help inform future program design to maximize savings.

Market Insight 5: due to the limited uptake to date associated with networked lighting controls, there is likely limited opportunity to pursue a program solely targeting retro-commissioning networked lighting systems. However, ensuring that commissioning efforts aimed at Integrated fixtures with Room-Based Controls, LLLCs, and NLCs will help capture the full measure potential. While the opportunity for retro-commissioning networked lighting controls is small, there is likely more opportunity associated with retro-commissioning programs that focus on non-networked LLLCs and fixtures with integrated

controls. As networked systems gain market share, there could be an opportunity down the road to increase savings through a targeted retro-commissioning program.

As part of this study effort, DNV previously forecasted the saturation, market share, and trend in net program savings associated with the ambient linear submarket using a stock turnover model. These forecasts were used as the future baselines to calculate recommended adjusted measure lives (AMLs).[1] In addition to this report, DNV delivered as set of recommendations on the savings factors and measure lives for new residential and commercial Advanced Lighting Controls (ALC) measures as part of the Connecticut X1931-4 ALC evaluation study. The interviews with lighting experts that supported the Connecticut X1931-4 ALC savings estimations were also used to support the market opportunities presented in this report. DNV will also be conducting customer surveys to estimate net-to-gross (NTG) ratios as part of the C2014 study to help understand where lighting programs have a higher influence in continuing to transform the C&I lighting market in Connecticut. Program Administrators have already provided DNV with data to support this effort, and a report will be available later in 2022 with these results.

[1] Study finalized and pending online posting

Table of contents

2 INTRODUCTION

While C&I lighting savings have historically accounted for a significant portion of savings in energy efficiency programs in Connecticut, the bountiful savings are forecasted to decline in the coming years due to LED market saturation and natural adoption. As program administrators look beyond traditional lighting programs, lighting controls and commissioning have come up as ways to continue to generate savings within the lighting market. However, deeper understandings of the markets are necessary to properly design and administer these types of programs.

On behalf of the Connecticut Energy Efficiency Board (EEB) Evaluation Administrators, DNV conducted surveys with five lighting experts to better understand the opportunities around TLED to LED luminaire conversions, adding enhanced lighting controls capabilities to existing LEDs, and commissioning advanced controls. These topics were selected during the scoping phase of this effort based on feedback from the Connecticut Evaluation Committee and Evaluation Administrator Team. This report serves as one of the key deliverables as part of the Connecticut C2014 C&I Lighting Saturation and Remaining Potential Study and presents key considerations for future program efforts. In addition to this report, later in 2022, DNV will also present results from customer NTG research aimed at identifying lighting measures and/or market segments in need of more program support. This will cover free-ridership and participant spillover for all C&I lighting measures across the Energy Opportunities, Small Business Energy Advantage, and Upstream programs. Lighting NTG for the Energy Conscious Blueprint program is covered under the C1902 ECB NTG and Baseline and Upstream Non-Lighting NTG Study.

2.1 Summary of Approach

The primary data collected to support this research effort came from in-depth interviews (IDIs) with five lighting experts conducted in April and May 2022. The five lighting experts were selected with support from the Evaluation Administrators and represent independent consultants, product managers, and industry thought leaders with experience in EM&V, implementation, product management, policy, utility EE programs, and trade associations. While these experts were asked about Connecticut specific topics, they bring knowledge from the national market and regional markets in the Pacific Northwest, California, Midwest, and the Northeast.

This survey effort supported the market opportunity needs of this survey as well as the savings estimation needs of the Connecticut X1931-4 ALC research. The survey guide is included in Appendix A. Responses to this survey have been summarized and anonymized. In addition to these survey responses, we have included relevant information from other research conducted in Connecticut and similar jurisdictions to provide additional context to expert interview responses.

3 DISCUSSION OF RESULTS

The following subsections present a summary of the results collected as part of the expert interviews and additional information gathered.

3.1 TLED to LED Luminaire Conversions

This subsection characterizes the opportunity to replace TLEDs with more efficient LED luminaires as TLEDs begin to burnout or customers seek to replace older TLEDs. A previous memo as part of the C2014 study effort characterized the overall linear submarket, so this report will focus on understanding the specific opportunities around increasing efficiencies within the LED stock.

The ambient linear submarket has historically been dominated by fluorescent lighting (T12, T8, and T5), and the market trend in the early 2000s had been to replace inefficient T12s with higher-efficiency T8s and T5s. Starting in about 2015, the market has been trending toward replacing all fluorescents with TLEDs. TLEDs offer a cost-effective way to replace

fluorescent technology with minimal impact to customer facilities and lighting arrangement. Recent forecasting in Connecticut as part of the first phase of this evaluation effort estimated that the ambient linear stock of TLEDs in the C&I sector was about 38%. This is expected to increase to 45% by 2025. The list below includes the different types of TLED technologies that are available in the market.[2] To be eligible for program incentives, TLEDs must be Design Light Consortium (DLC) Qualified. Type A, B and C products are included in DLC's Qualified Products List.[3]

- Type A LED (ballast driven) – directly replaces tradition linear fluorescent lamps, and no rewiring is required. These types of LEDs are plug and play; however, they rely on fluorescent ballasts but are not compatible with all ballasts. The lumen output of these lamps can be controlled by the existing ballast.
- Type B LED (direct wire) – requires rewiring the socket to the supply line voltage to bypass the ballast. When ballasts are failing or close to the end of their useful life, Type B LEDs eliminate the ballast but also have limited ability to control the lumen output.
- Type C LED (LED driver) – requires rewiring the fixtures to include an fixture mounted LED driver. These LEDs have more dimming capabilities and offer the longest life, but they also have the highest price point.

More recently, we have seen a growing presence of LED luminaires that can be even more efficient than TLEDs, are more visually appealing, and offer opportunities for increased savings with the integrations of enhanced lighting control capabilities. LED luminaires are estimated to account for approximately 20% of installed stock in 2022 growing to 30% by 2025. In the linear submarket, the market share (% of sales) for LED luminaires is expected to surpass TLEDs by 2023 or 2024. However, lighting experts are split on if they agree with this market share forecasts. One expert posits that TLEDs are, and will continue to be, more dominant because of their ease of installation and maintenance, but expects larger new construction and renovations to incorporate more LED fixtures in the future. Another expert believes that LED luminaires will become much more prevalent than TLEDs because, although TLEDs have offered an efficient and cost-effective next step for energy savings, they simply do not offer opportunities or non-energy benefits that luminaires do.

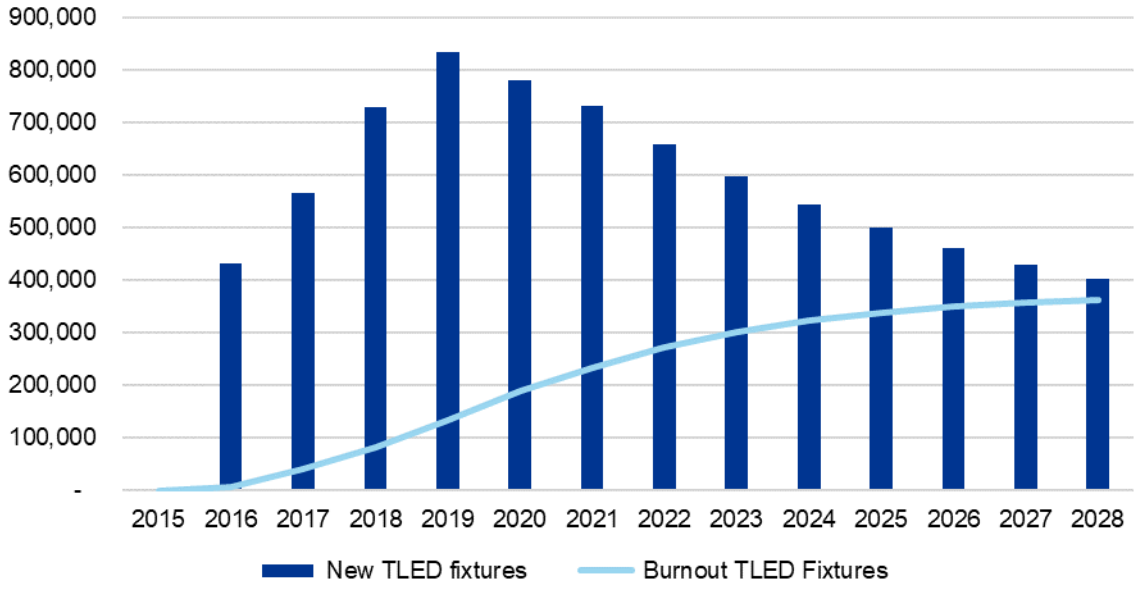
Lighting experts indicated that customers that installed TLEDs are moderately to extremely satisfied with TLED performance. This brings up the question about what customers plan to do as TLEDs begin to burnout. Since bulbs don't burn out all at once and customers are generally satisfied with their performance, experts tend to agree that customers will most likely pursue a one-for-one replacement with new TLEDs. Cost is the most common cited reason for this. The type of TLED technology that was installed will also impact customers decision about how to replace TLEDs as they begin to fail. If Type A TLEDs were installed, which rely on the fluorescent ballasts, and the ballasts begin to fail, the customer may be more willing to replace the fixture with an LED luminaire rather than replacing the ballast and the fixture with a new TLED fixture. A typical fluorescent T8 ballast has an effective useful life of 70,000 hours, so depending on when the ballast was installed ands what the facility operating hours are, these ballasts may last for many years without the need to replace. For customers with a Type B or Type C TLED, the customer may be more interested in the cheaper option to replace with the existing technology. While we have minimal insight into what portion of the TLED stock is made up for Type A, B, or C, Type A TLEDs are likely the most prevalent technology type installed in the market.

Space type and operating conditions can also be a driver in cost-effectiveness and could impact what replacement technology makes the most sense. For customers with smaller spaces and facilities, the cheapest option may be to replace bulbs with the same technology. However, for larger facilities or sites where increased control capability could lead to higher savings, it's possible that those sites would pursue a large retrofit or redesign project. DNV's forecast model shows that as the market reaches complete transformation, most of the TLEDs that will be installed each year will be going towards

[2] We do not currently have any estimates of what portion of the installed stock of TLEDs is comprised of each of these technology types.
[3] https://www.designlights.org/qpl/

replacing burned out TLEDs. Figure 3-1 is based on data from DNV's forecast model developed for Connecticut. The figure shows the forecasted rate of total new TLED fixtures installed each year (due to replacing failed lighting, retrofitting old light, or as part of new construction) compared to the total number of fixtures with TLEDs that are expected to burnout assuming the program continues as-is.[4] While we know that burnout happens at the lamp level, for simplicity, the model unit of analysis is at the fixture levels and includes assumptions about the number of lamps per fixture. In 2022, 41% of the TLEDs sold across the market are going to replacing burned out LEDs. By 2025, this is expected to increase to 68%.

Figure 3-1. Total number of new TLED fixtures installed compared to rate of TLED fixture burnout



Since the market for TLEDs is clearly established, there are minimal opportunities to transform the market with TLEDs. Even in the absence of the program, forecasted rates of TLED adoption are expected to increase due to the low price point and cost savings. Most lighting experts agree that the market share for TLEDs will be driven by maintenance for existing systems, and the opportunity for continued LED growth will be centered around LED luminaires, especially those with integrated or networked lighting controls.

In terms of burnout, TLEDs will continue to play a significant role in the market. However, for retrofit, there is general agreement amongst lighting experts that LED luminaires will continue to grow in popularity. For customers looking for additional non-energy benefits, like increased like light quality, comfort, and productivity, LED luminaires offer a better solution along with the increased savings. In new construction projects, LED luminaires are already playing a dominant role compared to TLEDs. One area that has received less investigation is possible differences in customer segmentation. It's possible that businesses and organizations within Environmental Justice Communities (EJC)[5] may not have experienced the same level of market transformation, and TLEDs could still play a role increasing energy savings.

Market Insight 1: The natural adoption of standard TLEDs has reached or is close to the peak of the market, and the price of TLEDs has decreased from historical rates to a point where there is now minimal opportunity for programs to generate significant savings moving forward. However, there may still be pockets of customer segments where TLED incentives can transform the market and deliver benefits, like in EJCs. Programs incentives for controllable technologies, like networked

[4] The rate of burnout in the early years may overstate actual burnout since TLEDs only began to show up in the market around 2015. TLEDs installed in the first few years are not expected to burnout after only a couple of years.

[5] https://portal.ct.gov/DEEP/Environmental-Justice/Environmental-Justice-Communities

TLEDs or LED luminaires with advanced or networked controls, are still needed to push customers towards controllable technologies to mitigate the impacts of stranded savings.

From a program standpoint, lighting experts don't expect there to be enough savings to incentivize a TLED to a standard LED luminaire replacement. Because there is high customer satisfaction and low costs associated with TLEDs, it is unlikely that customers would be convinced to participate in such a program. However, one lighting expert indicated that its possible a lighting program that targets replacing non-controlled TLEDs with LLLC could provide enough savings to be cost-effective. The Connecticut X1931-4 ALC memo recommends a 49% savings factor for networked lighting controls and commissioned LLLC. The savings factor for a non-networked, or networked but not commissioned, LLLC is only 38%. The higher savings generated from for networked lighting controls and commissioned LLLCs improve the cost-effectiveness; however more research is still needed to identify specific types of projects where this would be cost effective. While networked lighting controls and commissioned LLLCs are the best option for generating enough savings to warrant replacing existing TLEDs, more generic LED fixtures with integrated controls still represent savings opportunities in new construction and major renovation projects where the focus is not solely driven by lighting replacement.

Market Insight 2: Since many customers are satisfied with the performance of the TLEDs and there is some uncertainty around what types of situations or conditions where it would be cost-effective to replace TLEDs with LED luminaires, the opportunity for a targeted TLED replacement program is likely minimal. However, there may be some situations where replacing a TLED with LLLCs or luminaires with NLC may but cost-effective, but more work is needed to understand the benefit-cost ratio and customer willingness-to-pay for these types of projects.

3.2 Adding Controls to Existing LED Systems

While LED adoption has been increasing rapidly, there is concern that the lighting controls market has not kept pace with the LED market transformation. The best time to install various lighting control technologies is at the same time as the lighting installation. If lighting controls are not installed at this time, there is a high probability that there will be stranded savings by not also installing lighting controls. A 2020 study conducted in Massachusetts reported that only about 1% C&I customers had any type of advanced control.[6] In this case, advanced lighting controls refer to both LLLC and NLC. This effort investigated what opportunities there are to add controls to existing LED savings and tap into that pool of stranded savings.

There was general agreement amongst lighting experts that, from a economic perspective, there are few situations where it makes sense to add controls to existing LED systems. This is especially true in older LED fixtures or TLED fixtures. For Type B TLEDs, there are not control capabilities so the only path to add controls is through fixture replacement. For Type A and Type C TLEDs that either rely on the fluorescent or TLED ballast, there are some opportunities to add some control capabilities. However, this requires going into the fixture panels and the costs of LLLC retrofit kits have come down so much, it is almost easier to simply replace the fixture. For newer LED fixtures, the cost and difficulty in adding controls is less burdensome. Most DLC-qualified indoor luminaires are dimmable by default, so its technologically feasible and possible to add a control system after the fact. This opportunity is increasingly possible with the numerous wireless control systems now offered by manufacturers. Going forward, all DLC indoor luminaires will be required to be dimmable. In these cases, if controls aren't included at the time of installation, at least the luminaires will be capable of including controls at a future date.

Market Insight 3: it's challenging, although not impossible, to add controls after LEDs are already installed. For older TLED systems, this is especially challenging. For newer LED luminaires installed without controls, it may be easier to install

[6] https://ma-eeac.org/wp-content/uploads/MA20C11-E-LCR_Lighting-Controls-Final-Report_20210630.pdf

controls after a project is completed, especially given the technology improvements and new DLC standards for luminaires. Given these challenges, it's important to incentivize controls capabilities as part of the initial install/project.

Lighting experts added that customer awareness is still very limited across the country when it comes to advanced controls capabilities. Most customers likely know about general control capability like dimming or occupancy sensor, but their awareness of advanced controls, especially when it comes to differences between NLC and LLLC, is very minimal. In terms of lighting installers, experts were split on their perceptions of awareness across lighting installers. Two experts indicated that awareness is high, the other three reported that awareness was low across installers. Since customers tend to rely on advice from contractors, there is an opportunity to increase awareness and training around advanced lighting controls. This is discussed more in the following section on commissioning.

3.3 Commissioning Advanced Controls

Advanced controls provide a multitude of opportunities for the customer. Realizing these opportunities requires proper installation and commissioning. Understanding the potential savings that can be gained through commissioning and retro-commissioning is an important goal of this study phase. For the purposes of this study and in the context of lighting controls, we define these terms as:

- Commissioning - a systematic process of ensuring that all lighting systems perform interactively according to documented design intent and the owner's operational needs. The actual steps required for proper commissioning will be somewhat different for each type of system, building, and end user type; however, the steps generally include system design, system programming, calibration, and maintenance staff/end user training.
- Retro-Commissioning - a form of commissioning. Retro-commissioning is the same systematic process applied to existing buildings that have never been commissioned to ensure that their systems can be operated and maintained according to the owner's needs. For buildings that have already been commissioned, it is recommended that the practices of recommissioning or ongoing commissioning be applied.

Through expert interviews, it became clear that advanced controls are important in achieving savings potential, but without appropriate installation and setup, the added savings controls can provide are not always realized. Understanding that, many respondents also indicated the complicated nature of commissioning for lighting systems. The study team asked experts if these fixtures with integrated control and advanced lighting control systems are being set up correctly and to specification. While responses are anecdotal and not necessarily specific to Connecticut, two of the five experts indicated that these systems are rarely set up correctly, and another two indicated they were not close enough to the installation to know for sure but assumed these systems can often be set up incorrectly. One of the five indicated these systems are set up to manufacturer's specification, but that specification may not meet the needs of the facility. One expert indicated that "calibration and commissioning has always been an issue in lighting, and these systems are so much more capable and sophisticated, so it scales with that…It's very common for very sophisticated systems to be installed by sophisticated installers in sophisticated spaces and still require technicians to go out over and over to figure out issues."

Another expert noted that even though they have seen systems not set up to specifications and missing electric savings potential, the number of C&I facilities with these advanced control systems is quite small. Even though there is opportunity to commission and retro-commission advanced lighting controls, the limited current quantity of these systems in the field suggests limited aggregate savings potential for retro-commissioning at this time. The larger opportunity for generating program savings at this time is in encouraging sales of fixtures with advanced lighting controls or at least fixtures with integrated controls and ensuring all of these types of control technologies are commissioned correctly at the start. While these more advanced types of lighting systems have all sorts of capabilities, what actually gets installed and setup is still

uncertain. The best way to track this is for programs to collect information on to the extent that specific capabilities (daylight dimming, occupancy sensing, and trimming) are actually being deployed.

Market Insight 4: Savings from lighting controls systems are dependent on the installation and appropriate commissioning, which is dependent both on the space type and usage patterns. Pre-commissioned fixtures will have some savings, but don't necessarily maximize the savings opportunity. Continued contractor training is an important tool for ensuring that these fixtures are commissioned accurately. Tracking the specific controls capabilities of installed fixtures, and to what extent they are being deployed correctly, can help inform future program design to maximize savings.

Although they are considered advanced, market perception and portrayal of LLLCs have fallen into a grey area. As described by experts in these interviews, marketers, retailers, and distributors are starting to conflate LLLCs with other control options, which are similar to fixtures with integrated controls, but are not networked. This confusion suggests that people may think they are purchasing the full realized benefits with an LLLC measure, but in order for it to truly be a program qualified LLLC, it has to be networked to maximize the functional capabilities of the technology. As one expert put it, "LLLCs are a subset of NLCs… LLLCs do everything NLC does but does it at end node of the system, an NLC has sensor in the middle that controls fixtures that can talk to each other, but the smarts aren't at the fixture. LLLC has smarts at the end of the line at the fixture level, has all smarts that NLC has." Table 3-1 shows the recommendations for advanced lighting controls and their relevant savings factors found in a different study looking to update the states Program Savings Document (PSD). Through that study, similar findings showed that LLLCs are being sold, but not networked. Since LLLCs are a subset of networked lighting control systems, the CT X1931-4 study proposed the creation of an additional measure, Integrated Fixture with Room-Based controls to capture those fixtures that have LLLC capabilities but are not networked or commissioned.

Table 3-1 Advanced Lighting Control Recommendations from CT X1931-4 ALC PSD Phase 2 Memo

Measure	Description	2022 PSD SF	Proposed SF
Networked Lighting Controls (NLC)	An intelligent network of individually addressable luminaires and control devices for remote access by the user. NLC have fixture networking capabilities, individual addressability, occupancy sensing, daylight harvesting, high-end trim, flexible zoning, continuous dimming, scheduling, and cybersecurity.	49%	49%
Luminaire-Level Lighting Controls (LLLC) – Networked & Cx	Network-capable fixtures which integrates high-end trim, occupancy and daylight sensors into the LED fixture. Networked and commissioned.	49%	49%
Integrated fixture with Room-Based controls	LLLC that is not networked	N/A	38%[7]

Recognizing all of this, retro-commissioning of ALCs provides an opportunity for utility energy efficiency programs to derive additional savings although the total amount of savings is limited due to the low number of systems deployed at this point. Experts indicated commissioning and retro-commissioning is needed with both advanced lighting control systems and fixtures with integrated controls. However, due to the low quantity of networked lighting controls systems in the market, the

[7] 38% is highest savings factor associated with a non-networked fixture with integrated controls Per discussion with the EA team, this was agreed to be a reasonable assumption for a fixture with three integrated controls that is not networked or verified/commissioned.

largest programmatic savings opportunity for retro-commissioning exists for fixtures with integrated controls and LLLCs that have not been networked, which we are calling Integrated Fixture with Room-Based Controls[8].

Market Insight 5: due to the limited uptake to date associated with networked lighting controls, there is likely limited opportunity to pursue a program solely targeting retro-commissioning networked lighting systems. However, commissioning efforts aimed at Integrated fixtures with Room-Based Controls, LLLCs, and NLCs will help capture the full measure potential. While the opportunity for retro-commissioning networked lighting controls is small, there is likely more opportunity associated with retro-commissioning programs that focus on non-networked LLLCs and fixtures with integrated controls. As networked systems gain market share, there could be an opportunity down the road to increase savings through a targeted retro-commissioning program.

4 CONCLUSIONS

There is no clear solution that is going to fill the gap in declining lighting program savings. However, there are a few areas where program administrators can continue to transform the lighting market towards more efficient lighting and lighting with advanced controls. TLEDs were a great solution as customers began to transition away for traditional fluorescent lighting, and these customers are generally satisfied with their existing TLEDs. However, the TLED market is likely going to transition more towards a maintenance market for existing TLED systems while customer pursuing large retrofit projects and new construction projects will be focusing on LED luminaires. Since the price of TLEDs has dropped and the natural adoption of TLEDs has increased, program administrators should concentrate on the LED luminaire market and ensuring that new fixtures and lighting projects include advanced lighting controls capabilities.

The stranded savings associated with existing LED systems without controls are going to be difficult to capture at this point, so it is important to focus on maximizing the savings opportunity associated with controls at the time of sale. Continuing to incentivize lighting projects without any controls at this point will minimize the total amount of possible savings. However, as programs focus on increasing the rate of advanced controls, its essential that these systems are installed and commissioned correctly. Even if these systems are set up to specification, they need to be tuned to the needs of the facility. While retro-commissioning does provide an opportunity to generate additional savings, at this point, there is a very limited pool of resources available from a program standpoint. Rather, the focus should be on increasing training and ensuring that incentives support the proper installation and commissioning of these systems to maximize savings and demonstrate the benefits of these systems across the market.

[8] Integrated fixture with Room-Based Controls was decided as the name to be used in the case of an LLLC that is not networked and commissioned. This was decided on in the CT X1931-4 ALC study, as it is analyzing the proper measures for lighting controls to be used in Connecticut.

APPENDIX A LIGHTING EXPERT SURVEY GUIDE

4.1 Expert interview guide

CT Program Savings Document (PSD) Measure Update & Lighting future potential – Advanced Lighting Controls Market Actor Guide DRAFT

4.1.1 Study Objective

X1931: CT Program Savings Document (PSD) Measure Update – The primary objective of the X1931 study is to update entries for recently added residential and commercial Advanced Lighting Controls (ALC) measures incorporated into the CT Program Savings Document (PSD). Updates are supported by primary and secondary research in an effort to gain better understanding of advanced lighting control technology and market potential.

C2014: C&I Lighting Saturation and Remaining Potential – The primary objective of the C2014 study is to characterize the status of the C&I lighting market, forecast the remaining potential for lighting programs, and updated PSD parameters impacted by a rapidly changing market. As part of Phase 2, DNV is examining additional savings opportunities associated with the lighting market including the addition of advanced controls capabilities, retro commissioning, and TLED to LED Luminaire replacements.

Interview Objective and Approach

Due to both the of subject matter, the expert interviews scoped under both X1931 and C2014 will be conducted in unison. The objectives of these interviews are designed to support both efforts. The overarching goal of these interviews is to gather insights on the ALC industry, confirm or update relevant savings factors for new ALC measures, and understand market trends from leading experts in the lighting and ALC market. Table 4-1 aligns the study-specific research objectives with the study and questions. Table 4-2 provides a summary of the data collection approach.

Table 4-1. Study-specific research objectives and identifying survey questions

Research Objectives	Study	Question Number
Accuracy and appropriateness of current controls categories	X1931-4 and C2014	1-3
Common controls and customer familiarity with controls. Also targeting customer and expert familiarity with NLC/LLLC and differences.	X1931-4 and C2014	4-9
Appropriateness and calculation of savings factors. Differentiation between LLLC and NLC	X1931-4	10-13
Measure life	X1931-4	14-15
TLEDs: Satisfaction and replacement behavior	C2014	16-17
Future potential of TLEDs and LED Fixtures	C2014	18
Fixtures with integrated controls: barriers, replacement behavior, commissioning/RCx	C2014	19-21

ALCs: barriers, replacement behavior, commissioning/RCx	C2014	22-25

Table 4-2. Overview of data collection approach

Data Collection	Description
Population Description	Industry experts on advanced lighting controls
Sample Size	4 - 6
Instrument Type	Phone Interview
Survey/Interview Length	Approximately 45 minutes
Description of Contact Sought	Advanced lighting controls experts

4.1.2 Instrument: Interview Script

Interviewee		**Interviewer**	
Interviewee Company		**Interview Date**	
Interviewee Phone #		**Interviewee email**	

Introduction

Thank you for taking the time to talk with me today. As a reminder, we are currently working on a study in Connecticut looking at ALCs, and relevant savings factors and measure lives associated with those ALCs. The potential savings associated with various controls technologies and controls strategies can vary based on control type, proper installation, user knowledge, building type, and many others. We are hoping your insight can aid us in confirming or updating our understandings. We will reference the control strategies that I previously provided to you. While answering the following questions, please feel free to additionally offer any perspectives you may have on the market or controls technologies.

Would you be open to us recording this interview session? We would like to do so, because some of the questions designed to for an open-ended response which may require some additional review to capture all of your feedback. Also, we would like to include paraphrased versions of some of your responses in the report appendix. They will be anonymized, and your name/contact information will not be included anywhere.

Table 4-3. Measures and controls

Measure	Control Category	Control Type	Description	Current Savings Factor *(Relative to Manual On-Off Control)*
Commercial and Industrial Interior Lighting Controls	Basic Lighting Controls	Occupancy Sensors	Reduces lighting operation hours by switching off lighting in unoccupied spaces.	24%
		Daylight Dimming	Reduces lighting output to a set level or reduces lighting operating hours in response to natural daylighting using continuous, stepped, or on/off dimming capabilities.	28%
		High-End Trim	Reduces lighting output of individual lights or groups of lights to a set level continuously.	27%
	Hybrid Lighting Controls	Combination high-End Trim and Occupancy Sensors	Combines the capabilities of high-end trim and occupancy sensors	33%

		Combination High-End Trim and Daylight Dimming	Combines the capabilities of high-end trim, reducing the lighting output to a set level continuously, and daylight sensors, allowing lighting fixtures to reduce output to respond to daylight.	35%
		Dual Occupancy and Daylight Sensors	Combines the capabilities of occupancy and daylight sensors, allowing lighting fixtures to respond to occupancy and daylight.	38%
	Advanced Lighting Controls	Luminaire Level Lighting Controls (LLLC)	Integrates high-end trim, occupancy and daylight sensors into the LED fixture	49%
		Networked Lighting Controls (NLC)	An intelligent network of individually addressable luminaires and control devices for remote access by the user. NLC have fixture networking capabilities, individual addressability, occupancy sensing, daylight harvesting, high-end trim, flexible zoning, continuous dimming, scheduling, and cybersecurity.	49%

Residential Connected LED Lighting	Basic Lighting Controls	Connected LED Lighting	Connected LED lighting that allows for remote user control through Wi-Fi and/or a smart device. Allows for remote on/off, adjustment of brightness, and schedule setting.	29%
Residential Occupancy Sensors	Advanced Lighting Controls	Occupancy Sensors	Reduces lighting operation hours by switching off lighting in unoccupied spaces.	17%

[Share table without savings factors in advance of interview]

Questions

We would like to start by talking about your understanding of the different controls technologies and strategies.

1. Lighting controls present opportunity to bring additional savings though the strategies can be complicated. We have compiled a number of controls categories to try and capture the options available in the market. Do these categories allow us to capture all the differences in control capabilities?
   [Probing questions, if necessary]
   a. Are we missing any key lighting controls strategies you are seeing in the table that are not highlighted?
   b. Are there other important segmentations to capture?
   c. Are there too many categories?

2. Prior to this call, how familiar were you to these lighting control categories? (Basic, hybrid, advanced) Not at all familiar, slightly familiar, moderately familiar, very familiar, extremely familiar.

   a. [If they are familiar with advanced controls] Prior to this call and the explanation of our categories, how would you define the difference between LLLC and NLC.
   b. Advanced controls means different things to different people, how do you define advanced controls?

3. In your experience, how familiar are the typical C&I customers with these control categories? Residential?

   a. What control do you think customers most commonly think of if they report advanced lighting controls? Residential? C&I?

4. In your experience, what are the most common control technologies that are currently selected for commercial locations? Residential locations?

a. [If answer to 4 is non-advanced controls] At what point do you see advanced controls becoming common practice, if ever? Residential v C&I?
b. Do you have any insight into replacement practices?

5. Are there customers that are better suited for advanced controls capabilities?

    a. Is it due to size of facility? Hours of use? Building type? LLLC vs. NLC?

6. In your experience, how familiar are customers with the capabilities and differences of LLLCs and NLCs?

7. How familiar do you think installers are of the capabilities of LLLCs and NLCs?
    a. Do you have anything to add on this?

8. Can you provide insight into how you've seen LLLC and NLC systems typically set up and operated?

    a. Are NLCs and LLLCs installed correctly? Are functionalities being fully utilized? Are there installation issues due to existing lighting?

    b. Typical design conditions and control parameters? E.g., Is there a comprehensive building design to controls? Are they room-by-room? Fixture-by-fixture? Full building?

9. Are you seeing any trends in the sale/implementation of fixtures with integrated controls? By this we mean fixtures that have the capabilities of the hybrid controls such as occupancy paired with trim, etc. [Make clear not an advanced control]

    a. Are these more, less, or roughly equivalent in frequency to LLLC and NLCs?

We are now going to ask you a number of questions about the saving potential of ALC and their measure lifetimes.

10. From your experience, for the control strategies listed above, can you estimate the energy savings per fixture that they provide a facility compared to having more traditional manual switching or scheduling with a timer function prior to installation? For example, for high-end trim, what is the average percent reduction (%) of the fixture wattage? For occupancy sensors, what is the percent (%) reduction in operating hours due to the controls? Etc. [Enter in Table 4-4]

    a. [Probing Question] How do you determine these savings? Existing literature? Experience, primary data?

11. If added to a lighting system with typical occupancy and daylight dimming sensors, can you estimate the additional savings that NLCs and LLLCs would provide? [Enter in Table 4-4]

Table 4-4. Q10 and Q11 answer table

Measure	Control Type	Q10	Q11
Commercial and Industrial Interior Lighting Controls	Occupancy Sensors		-
	Daylight Dimming		-
	High-End Trim		-
	High-End Trim and Occupancy Sensors		-
	High-End Trim and Daylight Dimming		-
	Dual Occupancy and Daylight Sensors		-
	NLC		
	LLLC		

Res Connected LED Lighting	Connected LED Lighting	
Res Occupancy Sensors	Occupancy Sensors	-

12. [Read the existing PSD savings factors associated with the controls options: "These are the currently used savings factors associate with lighting controls in CT]
    [If respondent reports control savings >5% different from PSD, ask about those that differ:]
    Knowing your estimation differs from the existing estimation for CT, can you expand on your reasoning and why you may think they differ?

13. [If NLC and LLLC differ]
    Can you please discuss why you estimate LLLCs to typically save more/less than NLCs?

14. Do you think the savings from ALCs maintains, increases, or degrades over time?

    a. [If degrades] How fast? Can you provide a % per year?
    b. [If degrades] Is this the same, worse, or better than degradation from basic controls?

15. In your experience, do hybrid controls or ALCs last as long, less, or the same as the bulb that they are controlling?

We would like to spend the remainder of the conversation discussing potential opportunities for utility-sponsored energy efficiency programs to continue to transform the C&I lighting market.

16. TLEDs, tubular LEDs, are measures that have allowed customers to upgrade linear florescent systems cost effectively. From your experience, how satisfied are customers with the performance of TLEDs? (Extremely satisfied, Very Satisfied, Moderately Satisfied, Slightly Satisfied, not at all satisfied)

17. As TLED systems start to age and eventually burn out or fail, what do you think most customers will plan to replace them with? [Options include: A one-for-one replacement TLED, a complete replacement of the existing fixture with a new LED fixture, a non-LED tube or fixture, or other.]
18. Moving forward, do you think TLEDs or LED fixtures will have a more dominant market share in the C&I sector? Can you please explain?

19. Now I have a couple questions about fixtures with integrated controls.

    What are the primary barriers to adopting fixtures with integrated controls and those containing hybrid controls?

    a. [if they do not cite cost] Do you think that cost is a significant barrier?

    b. [Follow up] What types of program interventions are needed to increase the adoption of fixtures with integrated control and hybrid controls.

20. For customers that decide to retrofit their existing lighting systems and include the addition of controls, what are the primary motivations that influence their decision?

21. Based on your experience, are LED fixtures with integrated controls [hybrid, not ALC] generally set up to specifications and receive the necessary commissioning to confirm efficiency?

    a. Do you think retro-commissioning LED fixtures with integrated controls has the opportunity to generate additional savings?

22. We are going to shift a bit and focus specifically on advanced lighting controls. ALC technologies seem to be continually changing. Do you see any trends in the technology or capabilities of advanced controls? Please Explain.

23. What types of preexisting conditions are necessary for ALCs to be appealing to C&I customers?

    a. [Follow up] Does it ever make sense to retrofit existing LED lighting systems to include advanced lighting controls?

24. From your experience, are ALC systems generally set up to specifications? Do they received the necessary commissioning to confirm they are maximizing efficiency?

25. In your experience, have you seen a need for retro-commissioning from customers for lighting systems?

    a. Do you think retro-commissioning ALC has the opportunity to generate additional savings?

Closing

Thank you very much for your time today.

If applicable: I look forward to receiving the resources we spoke about. Would you like me to send a follow up email so that you have my contact? Clarify communication channel, thank, end call.

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